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Fire Spread and Plastics Pipes

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In this report the risk of spread of fire due to the passage of plastics pipes through fire-resisting elements was investigated using a gas-fired furnace similar to that used for fire-resistance tests specified in BS 476:Part8:1972. The results showed that the integrity of the element was usually lost quickly where plastics pipes penetrated simple wall constructions especially when thermoplastic materials of low melting point were used: chlorinated PVC gave the most satisfactory results. The report also ascertained the performance in fire of a domestic installation and accessed the risk of spread from one compartment to another through a system contained either within a protected shaft or enclosure. Floor stops within the protected shaft were shown to be necessary together with some control of protected shaft or enclosure construction.

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Fire spread and plastics pipes

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FIRE SPREAD AND PLASTICS PIPES

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The risk of spread of fire due to the passage of plastics pipes through fire-resisting elements was investigated using a gas-fired furnace similar to, but much smaller than, that used for fire-resistance tests specified in BS 476:Part 8:1972. The investigation concentrated on plastics pipes of sizes and materials which at the time were being used in the United Kingdom for above ground drainage installations. The work was divided into two parts, the first dealing with the performance of pipe/wall combinations under fire conditions and the second with pipe systems contained within protective walls or encasements.

The results showed that the integrity of the element was usually lost quickly where plastics pipes penetrated simple wall constructions especially when thermoplastic materials of low melting point were used: chlorinated PVC gave the most satisfactory results.

The second part of the investigation was to ascertain the performance in fire of a domestic installation and to access the risk of spread from one compartment to another through a system contained either within a protected shaft or enclosure. Floor stops within the protected shaft were shown to be necessary together with some control of protected shaft or enclosure construction.

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FIRE SPREAD AND PLASTICS PIPES

by M Curtis

INTRODUCTION

The use of plastics for pipework installations is continually increasing in the United Kingdom and a variety of materials have now been used for many years in industry and elsewhere for applications such as the transport of special fluids. Plastics are now widely used in domestic, office and similar buildings, particularly in piping installations for water supply and distribution and above ground drainage. This investigation concentrated on the materials used for above ground drainage systems because the variety of materials and sizes is larger than for water systems and the fire hazard associated with their use is likely to be greater. The investigation was of an exploratory and ad hoc nature and only pipe materials and sizes which were at the time being used in the United Kingdom were considered, concentrating on arrangements suitable for houses and flats. Limited deductions applicable to larger installations can however be made.

The investigation considered the risk of spread of fire and smoke associated with the passage of plastics pipe through fire resisting elements such as compartment walls and floors and separating walls. Whilst, in addition, the pipes constitute part of the fire load in a building and may emit toxic combustion products these risks were not specifically investigated although relevant information was obtained where possible.

A thermoplastic pipe is liable to soften and fall away during the course of a fire and the size of hole thus exposed will affect significantly the rate at which hot gases and smoke can penetrate into adjacent areas. The Building Regulations[1] limit the maximum internal diameter* to 38 mm for most combustible pipes penetrating fire resisting structures but extend this in the case of unplasticised PVC to 100 or 150 mm in certain areas.

Where combustible pipes exceed these maximum dimensions they must be contained within a protected shaft† where they penetrate compartment walls, floors or separating walls (Figure 1a). An exception is made in the case of PVC pipes penetrating separating walls in certain domestic buildings. In these cases, enclosure* of the system is required and where the floor slab is penetrated by the vertical stack it must be made good to provide a fire stop. The resulting arrangement is then similar to that of a protected shaft with fire stopping at floor level (cf Figures 1b and 1d).

A typical domestic above-ground drainage system using plastics materials consists of a soil-and-waste stack of unplasticised PVC, running vertically up the building and contained within an enclosure or a protected shaft. Lateral (near horizontal) branches connect sanitary appliances – sink, basin, WC and bath – to the stack. These branches pass through the enclosure or protected shaft walls. The top and bottom of the vertical stack are always open at some point to the atmosphere. The ends of the lateral branches are sealed with water seals at or near the appliance.

Under fire conditions the likely effect of the passage of plastics pipes through fire resisting elements is the loss of integrity of such walls and floors; when the pipe deforms or falls away a hole is formed which will permit the passage of smoke and hot gases. A protected shaft is designed to provide a separate fire compartment for the passage of services and failure would be deemed to occur if fire entered the shaft. In small installations with limited pipework however, failure might be deemed to occur only when fire penetrated an inhabited compartment other than that in which the fire originated. This investigation considers both of these possiblies; Part 1 – the length of time to loss of integrity of differing combinations of pipe and fire resisting structure and Part 2 – the probability of fire breaking into and out from a protected shaft or an enclosure in a typical domestic arrangement.

EXPERIMENTAL TECHNIQUE

All the installations tested were exposed in a vertical gas-fired furnace similar to but smaller than that used for testing walls and partitions to BS 476:Part 8:1972 (Figure 2), the specimen size being 1 m x 1 m. The temperature recorded by thermocouples within the furnace, sited 100 mm from the specimen face was made to follow the BS time-temperature curve by regulating the gas flow. Using this equipment the specimen could be subjected to a pressure of about 1 mm wg measured between the inside of the furnace and the external atmosphere. This pressure was coarsely controlled by the use of a damper on the exit flue and could in most instances be maintained at the stated level within ± 25%.

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*The Building Regulations refer to maximum internal diameters. Sizes referred to in this paper are nominal diameters; actual dimensions are given in Appedix 1.1 and the extract from the final draft of CP 304[2] has been added for comparison.

†A protected shaft for the purposes of this report, is defined as a vertical shaft passing through compartment floors and bounded by separating walls, compartment walls or protecting structures having the fire resistance required of elements of structure (Figure 1a).

*An enclosure is herein defined as bounded by separating walls, compartment walls, floors or vertical casing (Figure 1d). The casing is not an element of structure and may not need to have the fire resistance required of such elements.

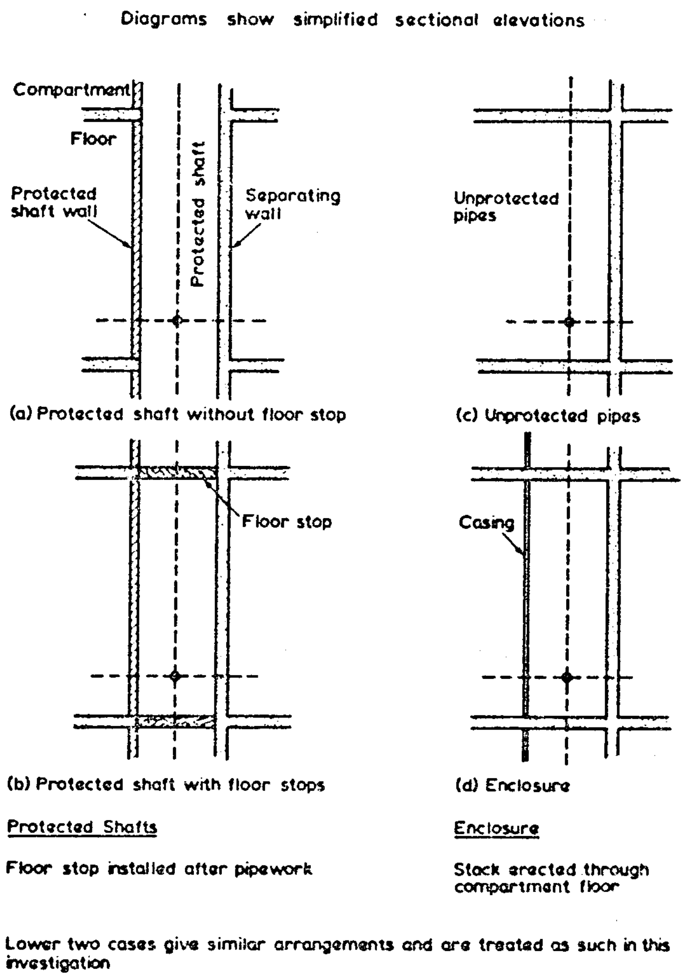

Figure 1 Possible arrangements for protecting pipework

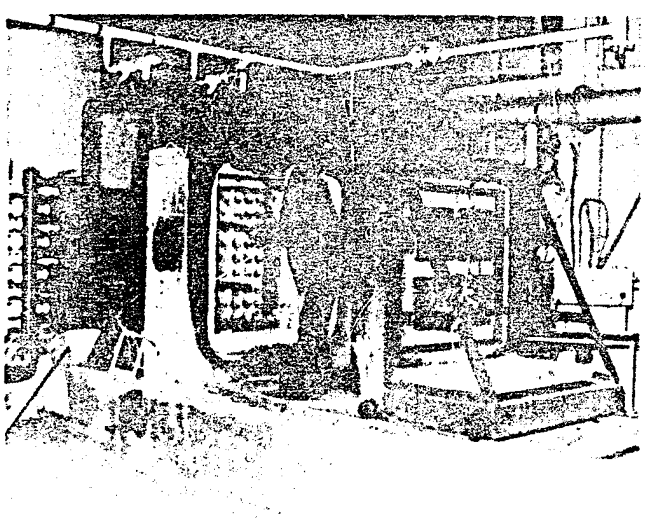

Figure 2 1 m x 1 m gas-fired furnace

EXPERIMENTAL PROGRAMME

PART 1 LOSS OF INTEGRITY OF SIMPLE PIPE/ WALL COMBINATIONS

1.1 Objective

The length of time to loss of integrity of a number of plastics pipes passing through walls of asbestos wall board or homogeneous building blocks was to be determined by visual observation.

1.2 Instrumentation

In this exploratory series instrumentation was kept to the essential minimum. The furnace temperature was recorded and the furnace/outside pressure differential measured at the level of the pipe penetration. The time to loss of integrity was noted.

1.3 Pipe/wall variables

(a) Pipe samples

The plastics materials and pipe sizes used are given in Table 1.

(b) Wall constructions

The wall constructions tested are given in Table 2.

(c) Pipe end conditions

Pipes of the type listed in Table 1 passed horizontally through the walls listed in Table 2 and terminated on the exposed face with one of the arrangements listed in Table 3.

(d) Jointing

Joints in small plastics pipe systems are usually made by a spigot and socket joint. This joint may either be solvent cemented or provided with a seal consisting of a rubber or plastics 'O' ring or similar device. Suitable pipes of 50 mm diameter were jointed by either means and as the type of joint was not thought to be significant no record of the joint is given. 100 mm diameter PVC pipes were joined by cemented or 'O' ring joint and the type used was noted.

(e) Protective sleeving

The use of sleeving was not intended to form a significant part of this investigation but as 100 mm PVC pipes wrapped with glass reinforced polyester (GRP) had occasionally been used in practical situations some pipes 'protected' in this way were included.

A complete list of the combinations examined is given in Table 4.

1.4 Results

The results of the tests carried out in Part 1 are summarised in Table 4.

1.5 Discussion (Part 1)

(a) Loss of integrity

Walls and other dividing elements of structure must, under fire conditions, maintain their stability, restrict the transfer of heat and prevent the passage of fire for a specified length of time, the last requirement being known as the maintenance of integrity. Plastics pipes are likely to have a major influence on the time to loss of integrity of a wall/pipe combination. The influence on stability and insulation is likely to be small.

(i) Open pipes (passage of fire towards an open stack). It is immediately clear that an open plastics pipe penetrating a fire resisting wall will, in the sizes investigated, fail quickly mainly due to the material becoming softened by hot gases and falling away from the wall. Time to failure is increased by increasing wall thickness and is likely to be increased by reducing pipe diameter. Under open conditions, it is unlikely that pipes of 50 mm diameter and larger of materials and pipe thickness similar to those examined can provide a satisfactory fire barrier when passing through walls of 100 mm or less. The type of support provided to the pipe through the partition will have a marked influence on its performance. Variations in pipe collapse, carbonisation and combustion may make substantial differences to the results especially with open pipes. For example, in test 1(d) the collapse of the ABS pipe provided a seal and gave a result that would not necessarily be repeatable.

(ii) Sealed pipes (passage of fire towards an appliance incorporating a water trap). Time to loss of integrity is increased in this circumstance, as the pipe is not subjected to the flow of hot gases. Notwithstanding the previous comments on variation it is possible to predict with some certainty the performance of a sealed arrangement. The data given in Table 4 allow a selection to be made of combinations of sealed pipes and walls that would be capable of providing an adequate fire barrier.

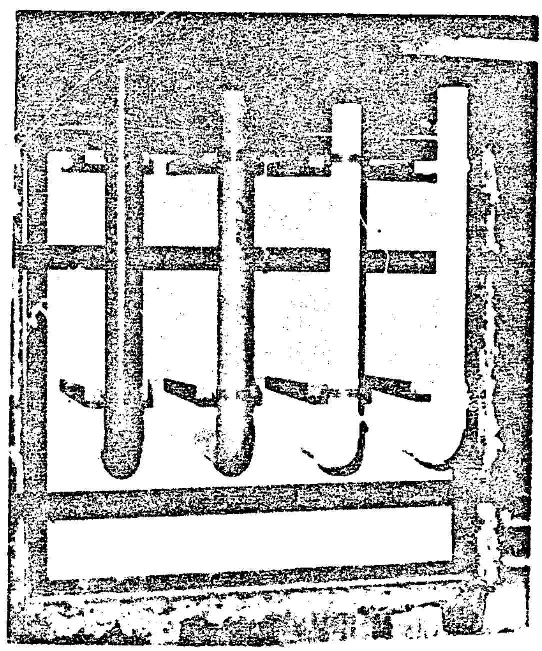

Figure 3 Prior to test 1a

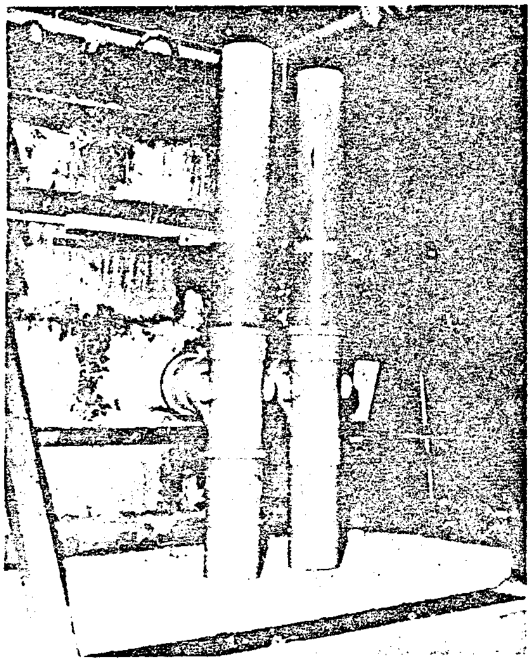

Figure 4 Prior to test 1i

(iii) Enclosures and protected shafts. From the above it is clear that it would be difficult to maintain for very long the integrity into an enclosure or shaft containing an open drainage stack but maintenance of integrity out again towards a sealed trap is a practical possibility.

(b) Effect of material

The indication from this restricted number of tests was that of the materials currently used for branches in drainage systems, UPVC and CPVC are likely to perform best in this type of fire test due to its reluctance to burn and to the production of a rigid carboniferous residue. PVC was shown to burn without a supporting flame once a sufficiently high temperature had been achieved. High density polythene and polypropylene gave poorer results than PVC in these tests as carbonisation does not occur and these materials melt more quickly and burn more readily.

(c) Fire transfer

It was thought that this test procedure gave little indication of the likelihood of the pipes themselves transfering the fire through the wall because the draught produced by the furnace and the deficiency of oxygen in the furnace gases appeared to inhibit flaming. However flaming did occur if outside air was introduced into the furnace (Test 1e). The CPVC flamed once a sufficiently high temperature had been reached under these latter conditions. Tests 1e, 1f and 1g all showed the greater risk of flaming with a smaller furnace/outside pressure differential but this was compensated for by a longer time to loss of integrity.

As the pipework fails hot gases and possibly flames may be transmitted through the open hole with the attendant possibility of fire spread: furthermore, heat transfer by direct radiation from the fire within the compartment cannot be ruled out. The open hole will also provide a path for smoke and toxic combustion products and the decomposing plastics materials might add to this hazard.

(d) Protective sleeves

Although insufficient data were obtained to draw firm conclusions on the effect of protective sleeves, the investigations suggested that the sleeve gave little added protection when the pipework was open (Figures 6 and 7) but appeared to perform better on sealed pipework. The performance of the sleeve would probably be improved if the pipework were bonded to the inside of it to prevent the softening pipes falling away. In the case of GRP sleeves an increase in flames and smoke occurred.

1.6 Conclusions (Part 1)

1 Plastics pipes of 50 mm diameter and PVC pipes of 100 mm when open to the atmosphere on the non-fire side were shown to fail quickly when tested in combination with non-combustible walls of 9 mm, 50 mm and 100 mm thickness.

2 Sealed plastics pipework gave improved performance.

3 Plastics drainage pipework in buildings requires protection either by siting within a protected shaft or by providing a fire-protecting casing.

4 In the sealed condition, and to a lesser extent in the open, the thickness of the wall, shaft or casing is likely to be a major factor in determining the time to loss of integrity of any combination of wall and plastics pipe of given size; the thicker the wall, shaft or casing, the longer the length of time to loss of integrity.

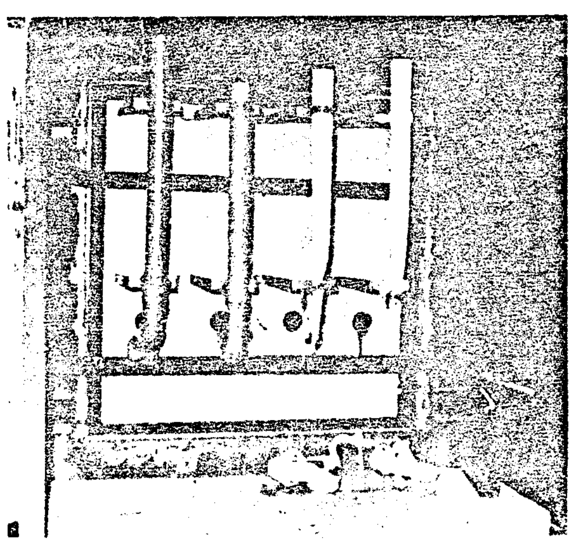

Figure 5 After test 1a

5 Although not examined it is likely that higher pressures would cause earlier failure. However the 1 mm wg used in this test is unlikely to be exceeded in practice.

6 By the use of enclosures or protected shafts to protect PVC services it is possible to provide adequate fire resistance between occupied compartments provided a degree of integrity failure between the fire compartment and the shaft or enclosure is acceptable.

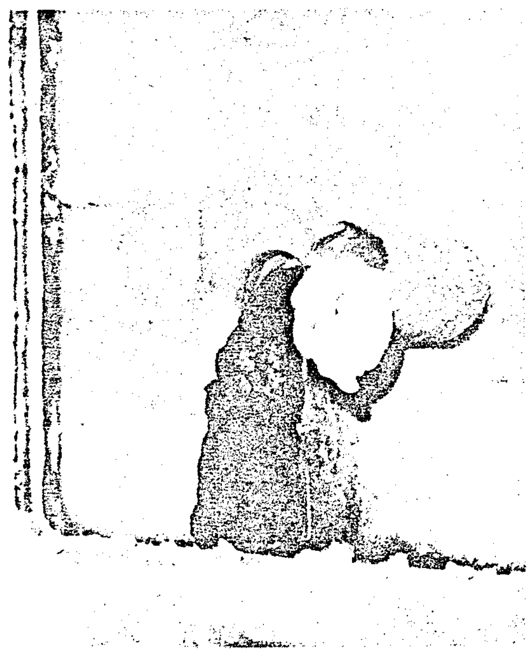

Figure 6 View from exposed side after test 1i

Figure 7 View from unexposed side after test 1i

PART 2 TESTS ON PLASTICS PIPES WITHIN ENCLOSURES AND PROTECTED SHAFTS

2.1 Introduction

In the above-ground drainage system of a typical housing unit near horizontal branches connect the sink, lavatory basin, bath and the water closet to a vertical stack. In multi-storey housing the vertical stack may be common to one or two columns of dwellings. The latter case is often referred to as a 'back-to-back' arrangement, a typical plan of which is shown in Figure 8. Typical sizes for the horizontal branches are:

sink branch	– 38 mm
basin branch	– 32 mm
bath branch	– 38 mm
WC branch	– 90 mm

In other types of buildings involving ranges of WC's or basins the sizes may increase to 100 mm and 50 mm for WC and basin branches respectively.

The vertical stack is likely to be enclosed for aesthetic reasons by casing or within a service shaft. If the pipes are of plastics or other combustible materials this should be a 'protected' shaft and its walls should have the fire resistance specified by the Building Regulations. In residential buildings, services may be enclosed in casings extending the full height of the room from floor to floor and their fire resistance may be less than that specified for other elements of construction.

It is common practice in the installations described above either to pass the vertical stack pipe through the floor and provide external casing around it from floor to ceiling (Figure 1d) or to extend the floor to surround the pipe after installation within a shaft (Figure 1b); this latter practice is known as 'floor stopping'. Both encasing and floor stopping give a similar final condition which might lead to a build up of smoke and combustion products at fire level within the protected shaft or enclosed area.

2.2 Objective

Part 1 of this investigation showed that if the progress of the fire is towards an open section of the pipework, the time to loss of integrity of any combination of a plastics pipe and a wall will be unacceptably short. Nevertheless, if the pipework is sealed this time is likely to be considerably longer. Thus if the plastics pipework is within a shaft or enclosure, it may be possible to so arrange the shaft or enclosure wall dimensions that even if fire penetrates quickly into the shaft, it will take longer to break out again. The objective of these Part 2 tests was to examine in the 1 m x 1 m furnace (Figure 2) typical pipe and shaft arrangements to determine the time taken for fire to break into and out of the shaft. Conditions within the shaft were monitored. The sizes of shaft and pipework used were compatible with the conditions in a domestic building. The results obtained were intended to predict performance only in this situation but may also be used as guidance for larger installations.

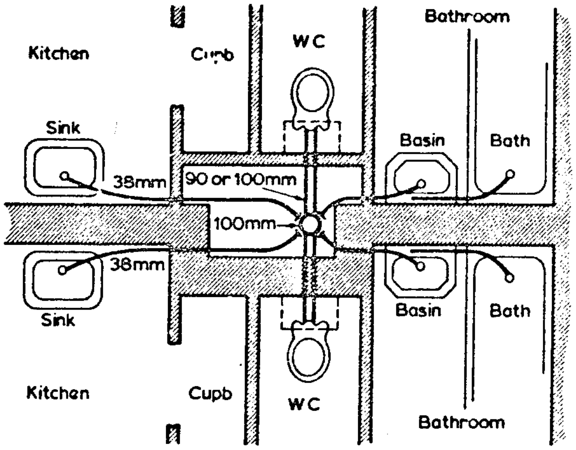

Figure 8 Diagrammatic plan of a typical 'back-to-back' drainage system

2.3 Description of equipment

A test cabinet measuring approximately 1 m x 0.3 m x 2 m high was constructed of 12 mm asbestos board and metal framing (Figures 9, 10 and 11). Vertical partitions of 12 mm asbestos board divided the area into three equal parts giving three shafts. Other materials were added to or replaced the section exposed to the 1 m x 1 m furnace.

A reinforced glass window – 100 mm wide and the full height of the cabinet on the unexposed back wall of each shaft allowed visual observation of the pipework and smoke within the shaft. Three shaft arrangements were examined in each test. Each shaft had a fire stop 150 mm from the base and 300 mm from the top. The shafts were closed but joints were not sealed. In each shaft a 100 mm stack ran vertically through the centre and in all but one case the stacks were of PVC. Each stack stood on the base (providing a seal) and was open at the top. One or two open horizontal branch pipes passed from the furnace into the shaft and joined each vertical stack. Above the upper floor stop a horizontal branch pipe passed out from the shaft. This pipe was sealed to simulate the existence of a water trap. In the later tests (2(d), (e) and (f)) horizontal branch pipes were introduced into the shaft through the unexposed back wall and/or through the side walls. Specific descriptions of the pipe arrangements for each test are given in Table 5 and shown diagrammatically in Figures 12-15. The sections of the shaft above and below the upper fire stop are referred to as the upper and lower compartments respectively.

Different constructions were used for the wall exposed to the furnace and in the last test the unexposed back wall was thickened to 100 mm by the introduction of block-work.

2.4 Instrumentation

Furnace temperature

The temperature in the furnace was measured by four thermocouples positioned 100 mm from the exposed face of the cabinet and the gas supply to the furnace controlled to provide the temperature-time curve specified in BS 476:Part 8:1973.

Other temperatures

Temperatures were measured by thermocouples within the protected shaft above and below the upper floor stop and within the vertical stack below the upper floor stop as shown in Figure 12.

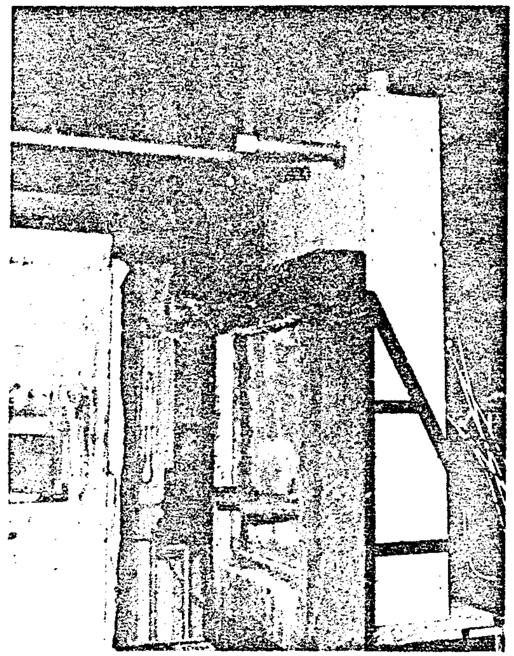

Figure 9 Cabinet mounted on trolley prior to test 2a viewed from furnace side

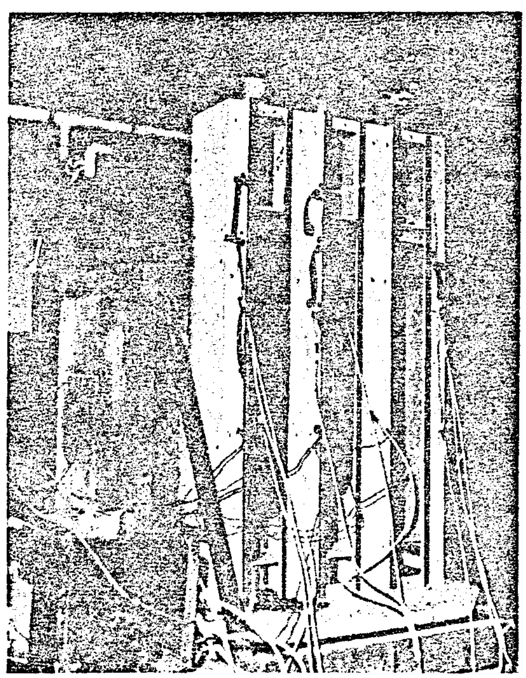

Figure 10 Cabinet viewed from unexposed side after test 2a (reinforced glass window removed)

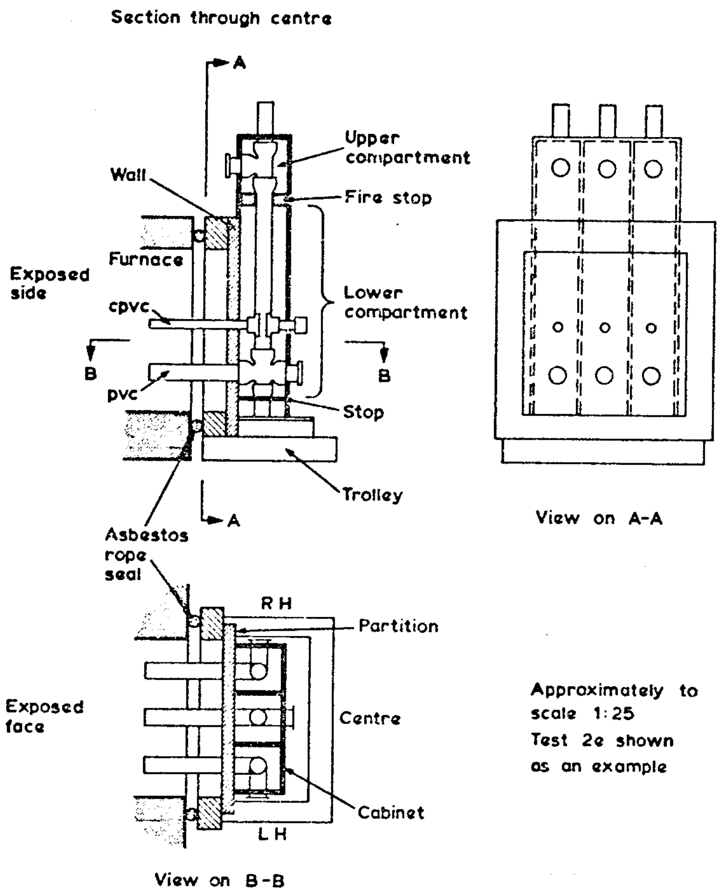

Figure 11 Diagram of test cabinet, furnace and furnace trolley

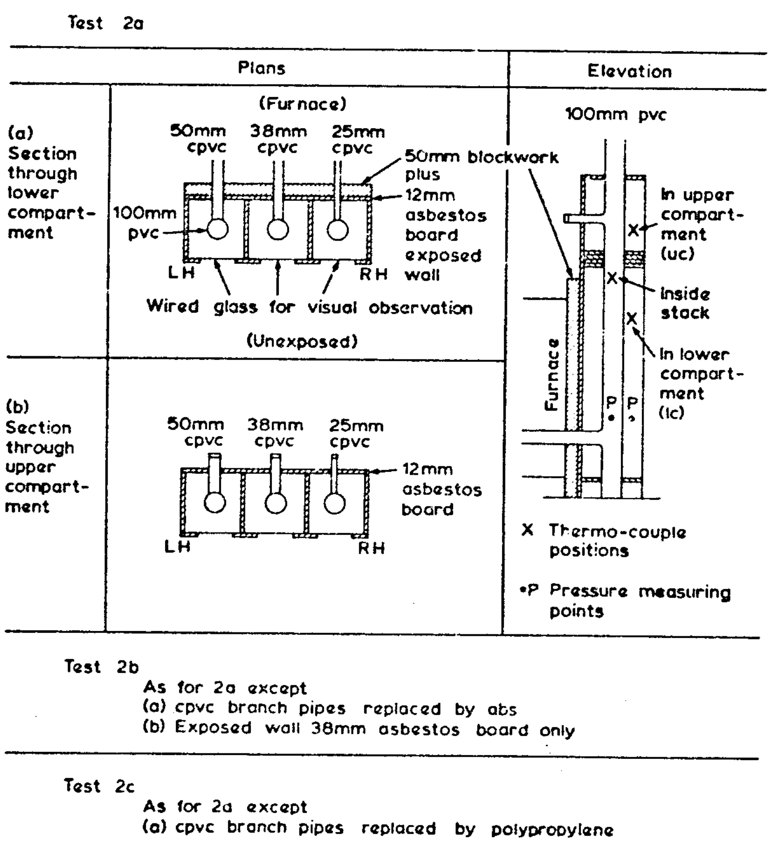

Figure 12 Tests 2a, 2b and 2c – Diagrammatic layouts

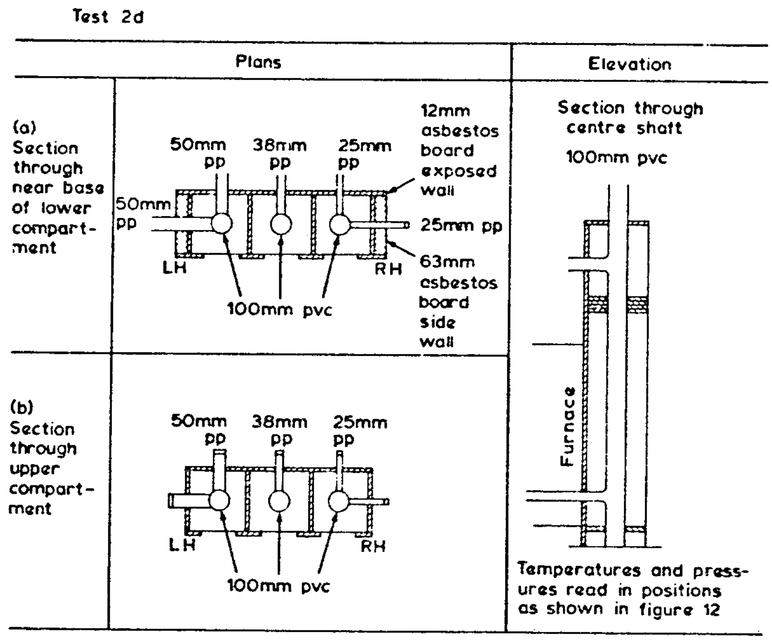

Figure 13 Test 2d – Diagrammatic layouts

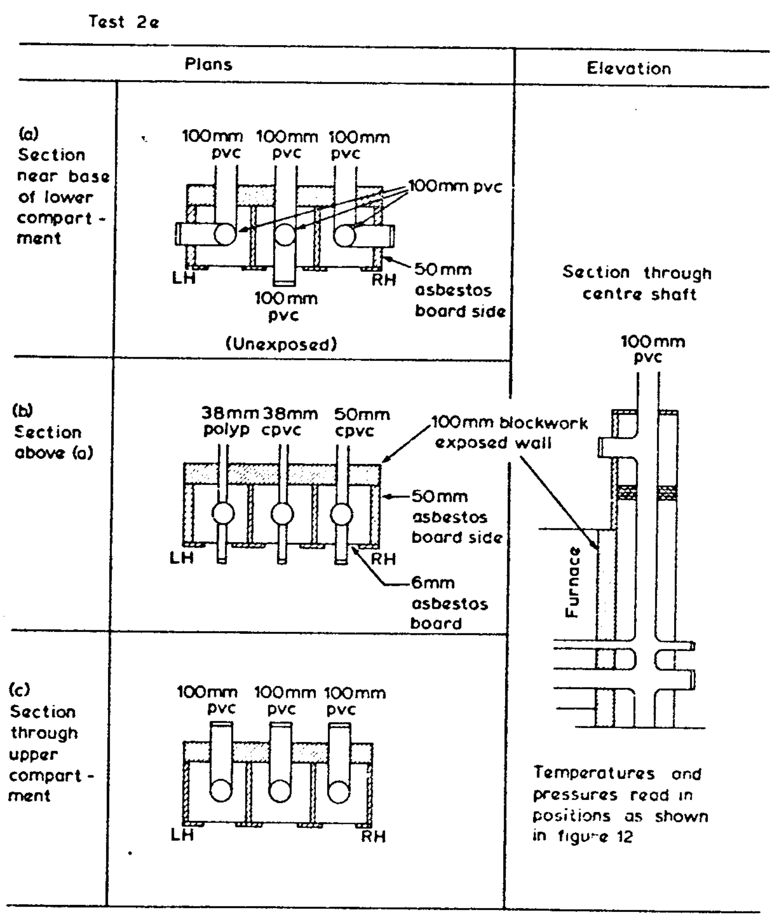

Figure 14 Test 2e – Diagrammatic layouts

Test 2f

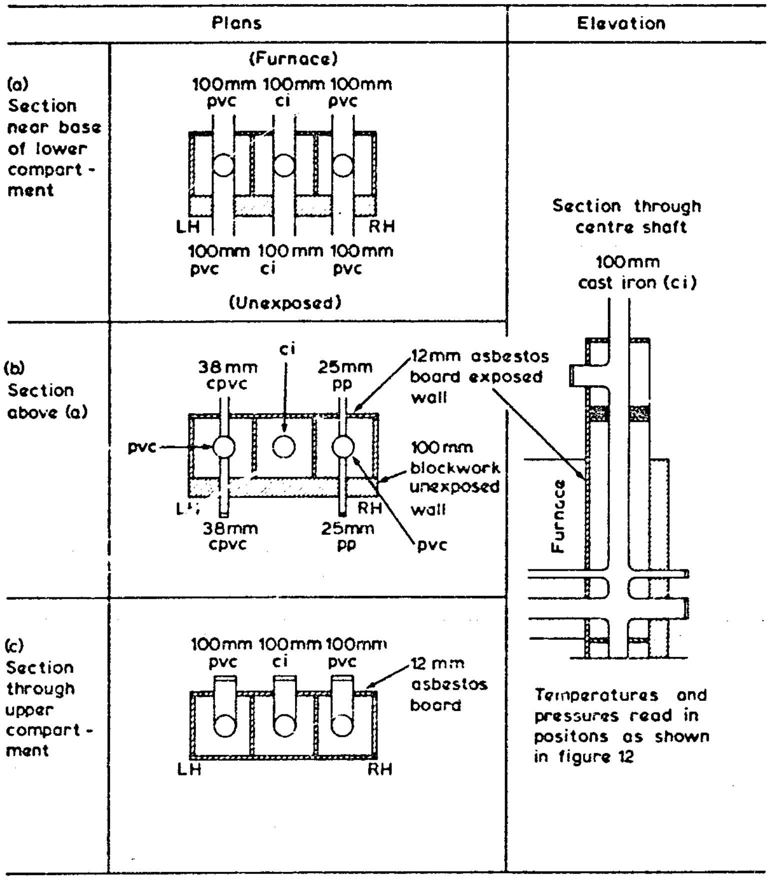

Figure 15 Test 2f – Diagrammatic layouts

Pressures

Indications of the pressure conditions were obtained using open ended copper tubes inserted into the furnace, the shaft and the vertical stacks. Each tube was inserted at 90^{o} to the predominant air flow. It was thought that as pressures were so variable and uncontrolled more sophisticated measurements were unwarranted. Positions at which pressure measurements were made are shown in Figure 12.

2.5 Pipe/wall variables

All combinations examined are illustrated diagrammatically in Figures 12-15 and listed in Table 5.

2.5.1 Tests 2(a), (b), (c) and (d) represented simple arrangements in which branch pipes of the materials examined in tests 1(a), (b), (c) and (d) were examined in the more practical situation of entering an enclosed shaft and connecting with a vertical stack. Various pipe sizes were used to determine the effects due to this factor on the comparative severity of conditions within the shaft and on the possibility of fire spread from compartment to compartment.

2.5.2 Tests 2(e) and 2(f) examined the larger 100 mm pipes likely to be encountered in the practical situation as WC branch pipes.

2.5.3 The possible arrangements of two WC branches discharging into the same stack was examined.

2.5.4 The 'back-to-back' arrangement when branches enter the enclosed shaft and join the stack from opposite sides was examined in arrangement 2e/centre and test 2f.

2.5.5 A possible layout of sanitary accommodation in a pair of dwellings so arranged to give back-to-back connections to the soil and waste stack is shown in Figure 8. Arrangements 2e/left hand and right hand examined possible alternatives.

Results

A summary of temperature conditions and comments on results are given in Table 5. Complete temperature records are given in Appendix II.

(a) Waste branches pipes up to 50 mm – Tests 2a, 2b, 2c, 2d

Tests 2a, 2b, 2c and 2d each consisted basically of a 50 mm, a 38 mm and a 25 mm waste pipe passing through a wall and connecting to a 100 mm stack. Damage occurred more quickly within the lower compartments penetrated by the larger pipes. This is clearly shown in Figures 16 and 17. It should be noted that the conditions shown in these figures are after 120 minutes and 100 minutes exposure respectively.

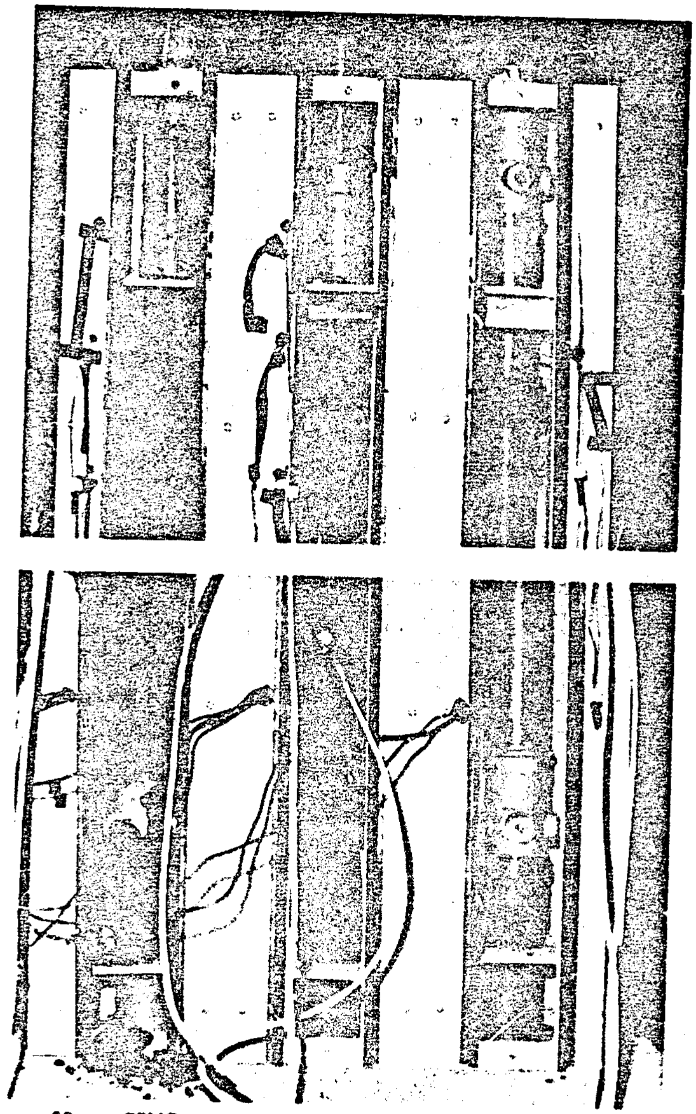

Figure 16 After test 2a. Showing variation of damage due to size of CPVC horizontal branch pipe. Duration of test: 115 min

Comparison of Tests 2b and 2c suggest that the type of branch pipe material used influences the conditions within the lower compartment for an initial period but after longer periods of exposure the thickness of the exposed wall and the pipe diameter are the significant factors. The other tests although not giving a direct comparison did not contradict this statement.

The thickness of the wall exposed to the heating conditions was shown to have a considerable effect on the conditions within the lower compartment. Tests 2c and 2d provide a direct comparison. (Figures 17 and 18.)

The PVC stack burned when temperatures within the lower compartment reached about 350°C.

In no instance was there a loss of integrity between the lower and upper compartments due to failure of the pipe/floor stop combination. Upper compartment temperatures appear to be related to lower compartment temperatures, 100°C being reached in the upper when the lower reached about 300°C. Above these temperatures distortion of the stack in the upper compartment occurred (arrangement 2d/1h – Figure 15).

(b) 100 mm branch pipes – Tests 2e and 2f

In all arrangements examined here two 100 mm branch connections were made into the vertical stack, one branch passing through the exposed wall and the other passing through an unexposed wall. In arrangements 2f and 2e/centre a 100 mm branch passed through the unexposed back wall of the shaft – a direct back-to-back arrangement. In arrangements 2e/1h and 2e/rh a 100 mm branch pipe passed through the unexposed side walls. All pipes through unexposed walls were sealed. Until loss of integrity occurred through an unexposed wall the condition was not significantly different from that with a single open branch connection through the exposed wall.

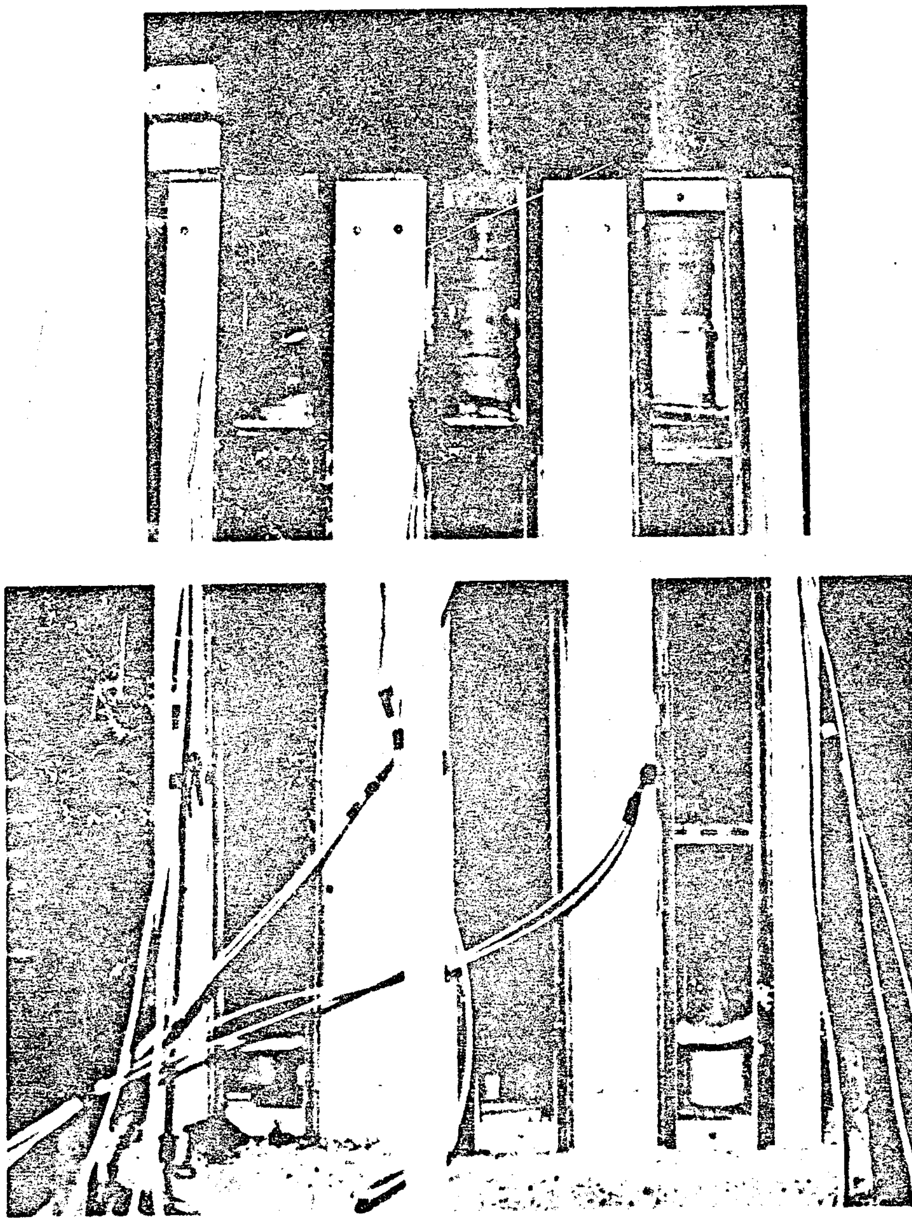

Figure 17 After test 2b (75 min). Variation due to pipe size (50 mm on right, 25 mm on left) and protection given by floor stop to stack higher up clearly shown

Arrangement 2f/centre used a cast iron 100 mm stack but was otherwise similar to 2f/1h. Arrangement 2f/rh did not include an upper floor stop but was otherwise similar to 2f/1h.

Lower compartment temperatures in all three arrangements in Test 2e and arrangement 2f/1h, when compared with earlier results, appear to indicate that when 100 mm branches are used compartment wall thicknesses up to 100 mm do not have a significant influence on the conditions in the lower compartment. These conditions are dictated by the large aperture through the wall left by failure of the 100 mm branch.

Comparison of arrangements 2e/centre and 2f/1h indicate that one influence on the loss of integrity from the lower compartment is the thickness of the unexposed wall. In arrangement 2e/centre, integrity was lost through the back wall (6 mm asbestos wall board) at 44 minutes.

In arrangement 2f/1h, integrity of the 100 mm pipe through the 100 mm unexposed back wall was maintained for 90 minutes. Integrity was not lost through the side walls in arrangements 2e/1h and 2e/rh.

Burning of the PVC 100 mm stack again occurred when lower compartment temperatures reached about 350°C.

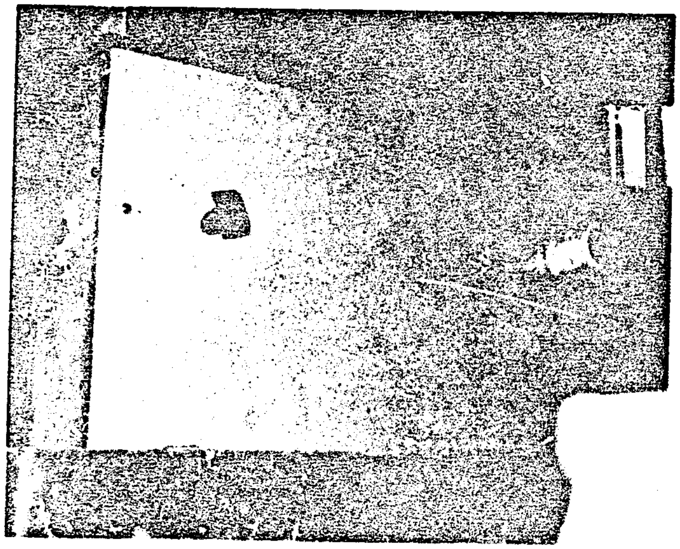

Figure 18a Front

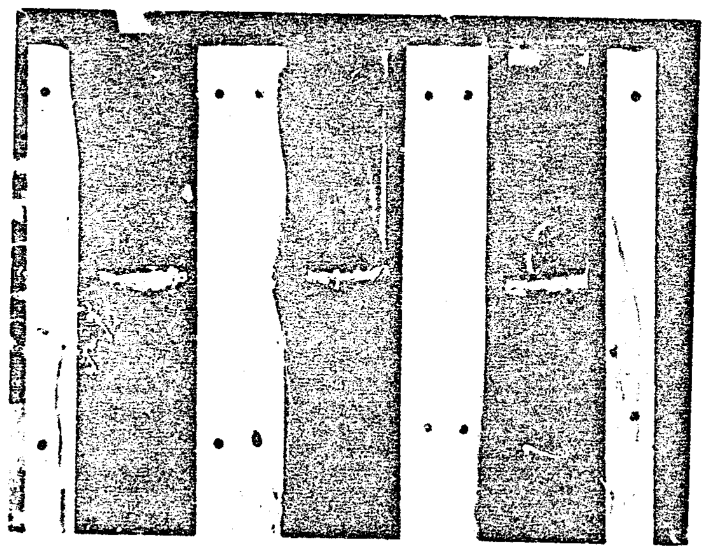

Figure 18b Back

Figure 18 Test 2d. Upper compartment after test (65 min). Considerable distortion inside compartment (some occurring after end of test – Figure 18b). Integrity between upper and lower compartment believed to be intact at end of test. Integrity of branch (sealed) pipes intact – Figure 18a

The upper compartment temperature again reached about 100°C when that of the lower compartment reached 300°C. Above these temperatures distortion of the stack in the upper compartment began (Figure 19).

(c) Comparison of a PVC system with a cast iron system – Arrangements 2f/1h and 2f/centre
Arrangements 2f/1h and 2f/centre provided a direct comparison between the same arrangement in PVC and cast iron. As expected no loss of integrity occurred with cast iron. However, the temperature in the upper compartment rose more rapidly due to the increased thermal conductivity of the pipe materials and to the flow of hot gases in the cast iron system being unobstructed unlike that in either the similar PVC arrangement or any previous test.

(d) Comparison of arrangements with and without fire stops – Arrangements 2f/1h and 2f/rh
Arrangement 2f/rh was virtually the same as 2f/1h but for the exclusion of the upper fire stop. Burning in both arrangements commenced before 60 minutes. In arrangement 2f/rh, without a fire stop, the complete stack was destroyed and integrity lost from the upper compartment at 49 minutes. In the fire-stopped arrangement integrity through the fire-stop and also from the upper compartment was still intact at the end of the test (85 minutes). Figure 21.

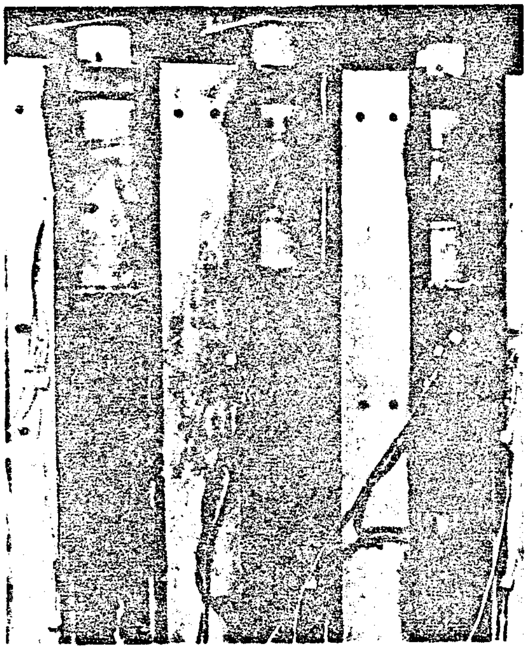

Figure 19 After test 2e. Upper compartment stacks in lower compartment completely destroyed. Stacks in upper compartment protected by floor stud (much of the distortion shown occurred well after cessation of test)

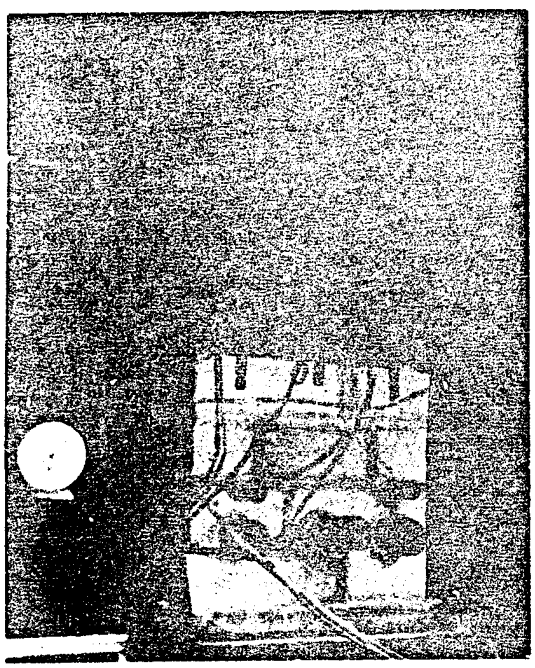

Figure 20 Test 2f. At 4[illegible] [illegible]utes

2.7 Discussion of results

2.7.1 Performance considerations

(a) Criteria for failure

From the point of view of fire spread it is not considered necessary to enclose most non-combustible pipework within a shaft or enclosure; however this is usually done for appearance considerations.

It may not be necessary to enclose small diameter plastics pipes within protecting structures but again it is thought to be preferable both to prevent damage by minor fires and other accidents and for the aesthetic reason suggested above.

For the sizes and types of pipework arrangements examined here, however, protection is usually necessary to comply with the Regulations. This protection may take two forms: a protected shaft or an enclosure. These forms are shown and explained in Figure 1.

With constructions of this type two criteria of failure are possible: (a) the more rigorous, in which failure is considered to have occurred at the time of failure of fire resistance of the exposed protecting wall and (b) in which failure is considered to have occurred at the time of failure of fire resistance of the total barrier between the fire compartment and any other compartment.

Part 1 of this investigation has shown that if criterion (a) is considered, a failure due to loss of integrity may occur very quickly if open pipework of plastics material is used. Combinations of thick walls and sealed pipes of 50 mm id or less should satisfy this criterion but the use of larger pipes would require precise test evidence of fire performance.

In small installations such as the domestic arrangements investigated in Part 2, fire is unlikely to originate within the shaft and limited pipework will contribute little to the fire load. It is therefore thought that in these circumstances criterion (b) would provide reasonable protection against fire spread as has been suggested elsewhere[4].

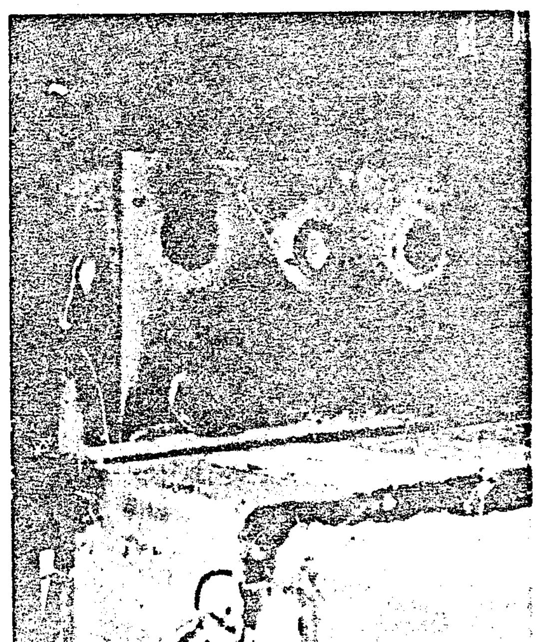

Figure 21 After test 2f. Loss of integrity from upper compartment

Walls of protected shafts are normally expected to have the same fire resistance as other elements of the structure and to have this resistance from both sides. If it is accepted that the criterion of failure is that of failure of the total barrier, for shafts which contain only a limited fire load, the fire resistance requirement for the shaft walls might be reduced. This investigation showed that, providing a satisfactory floor stop was fitted, the protection given by the structural walls and casings in the system tested was adequate to prevent fire spread from one compartment to another via the combustible pipework during at least a 1 hour fire resistance test.

There is no difference between the possibility of fire spread through a system in which the main piping is enclosed in a protected shaft with floor stops adjacent to a structure wall and a similar system which is 'encased'.

Hence for both systems the important question is the degree of fire resistance which is needed for the casing; it would appear from the tests that half the fire resistance required from other elements of structure would be adequate subject to a minimum of ½ hour measured from both sides to avoid the possibility of structural failure*. Certainly, provided the wall or casing is thick enough to prevent failure of the junction between the pipe and the wall on the unheated face, full insulation does not appear to be necessary.

(b) Vertical fire spread to other compartments – Floor stops

(i) Enclosures

Since the term 'enclosure' implies the passage of pipes through the floor and the addition of casing enclosing the pipes between floor and ceiling, consideration of horizontal floor-stopping to provide vertical separation does not arise.

(ii) Protected shafts

Fire stops within the protected shaft are not normally required by the Regulations. The early tests in Part 2 suggested that with combustible pipes, fire stops should be provided in order to minimise spread of smoke through the building, to localise damage to the drainage system and to prevent collapse of large sections of pipework into areas in close proximity to the fire. Figures 16, 17, 18 and 19 all show the protection given to pipework higher up by the floor stop. Because of the obvious necessity for a floor stop, only one arrangement was tested without a fire stop – (2f/right hand.) The complete stack in this example collapsed at about 29 minutes. Figure 20 shows test 2f at about 40 minutes with the left hand stack intact at the upper level. Failure occurred in test 2f/rh at 49 minutes when integrity was lost, (for the only time in the test series, from the upper compartment (Figure 21)). This loss of integrity seems to have occurred not solely due to the temperature in the upper compartment but also to the disturbance caused by the collapse of the stack.

It is suggested that the floor stopping should be solid, non-combustible and of equal thickness and fire resistance to the compartment floor through which the protected shaft passes and be smoke-tight and adequately supported. All pipes passing through the floor stop should be fire stopped with a suitable material, special attention being paid to those pipes requiring sleeving for thermal movement.

Penetration downwards is much less likely than upwards and was not experienced in these tests. The floor-stopping suggested above would give satisfactory protection.

Providing the floor stops are constructed as recommended above the section of protected shaft will perform in the same way as an enclosure for which some relaxation is provided for the passage of PVC pipes through separating walls into such areas.

(c) Horizontal fire spread

Fire and/or smoke may penetrate from the fire compartment by way of the shaft to compartments above or below and to other compartments on the same level. Resistance to penetration to areas above or below is increased by the provision of a floor-stop as shown above. Horizontal penetration is more difficult to contain especially if sections of the same piping system are involved (see Figure 8). The wall opposite to that exposed to the fire is more vulnerable than the side walls due to the greater intensity of direct radiation through perforations in the exposed wall left by the failure of plastics pipes. In the type of domestic circumstances envisaged in Part 2 of this investigation sections of the shaft wall structure may be fairly substantial due to requirements other than those for fire, viz structural or sound insulation. Tests 2e and 2f suggest that a combination of a relatively thick wall (100 mm is suggested as a minimum) with a thinner one will give satisfactory results. The thicker wall is assumed to be a separating wall and must have the full fire resistance required for an element of structure. The thinner wall is provided by the casing or a protected shaft wall and reduced fire resistance may be adequate; the thickness will determine the time to failure and minimum recommended dimensions are given in Table 6.

The 'straight through' 100 mm pipe in the centre compartment in 2e failed at 44 minutes with an unexposed wall of only 6 mm thickness but similar pipes, offset through 25 mm walls retained their integrity suggesting that the thickness requirement given above would give adequate protection. In the comparable arrangement with fire from the other side (test 2f/left hand) integrity was maintained but failure through the 100 mm wall was thought to be imminent at 90 minutes.

*These tests, however, were confined to the use of asbestos insulation products which did not suffer stability failure over the test durations involved.

In test 2e, right hand and left hand, integrity was maintained through the side walls to the end of the test (65 minutes). Although the side was much thicker (25 mm) than the back (6 mm) in this case, it is likely that useful benefit would be gained if entries into the shaft are not directly opposite one another. Pipes through unexposed walls are not then exposed to excessive direct radiation from the fire when failure through the exposed wall occurs.

(d) Fire transfer

As in Part 1, little indication of fire transfer was given by this test procedure. Lack of oxygen in the furnace gases inhibits flaming even of those materials known to be highly flammable. However, it is thought that the combustion products from a fire giving the high temperatures of the BS time/temperature curve are themselves likely to be deficient in oxygen. Fires not consuming the major part of the available oxygen are likely to be less hot. The suggestions made above for the construction of floor stops and shaft walls are likely to contain fire spread in any conditions. In systems such as those examined, constructed primarily from PVC, flaming only occurs after a considerable time when a high temperature is reached. In these circumstances the fire would probably be so large as to make the contribution to the fire from the piping material insignificant.

(e) Smoke and smoke spread

The production of smoke and toxic gases was shown to be a substantial problem in the fire performance of plastics pipe systems. In the type of system examined the hazards resulting from the spread of smoke are likely to be greater than is the risk of fire transfer. Thermal decomposition of a quantity of PVC can produce up to 50 per cent HCl by weight[5]. In all tests of Part 2, considerable quantities of smoke were evolved. This leads to the conclusion already drawn above that every effort must be made to contain the products of plastics combustion within the fire compartment and its associated section of service shaft. The need for floor stops and good fire-stopping around pipes is stressed again.

(f) Materials examined

Part 1 has shown chlorinated PVC to be the best material under the type of fire test conditions investigated in that part. PVC and chlorinated PVC pipes given reasonable support (partly by the thickness of the wall) remain in position, decompose and carbonise leaving a rigid, brittle carbonaceous residue. This effect considerably assists the performance of the larger (and thicker) 100 mm pipe. Partly for this reason PVC was the only larger plastics pipe examined in Part 2. It is stressed that the comments made here and the conclusions drawn later on the use of 100 mm pipes apply only to PVC. It is believed that no other plastics material currently readily available as drainage pipework would perform as well. The carbonising effect of PVC is clearly shown on Figure 22 which shows the remains of the 100 mm PVC pipes through the 100 mm back wall of test 2f/left hand and right hand. The carboniferous

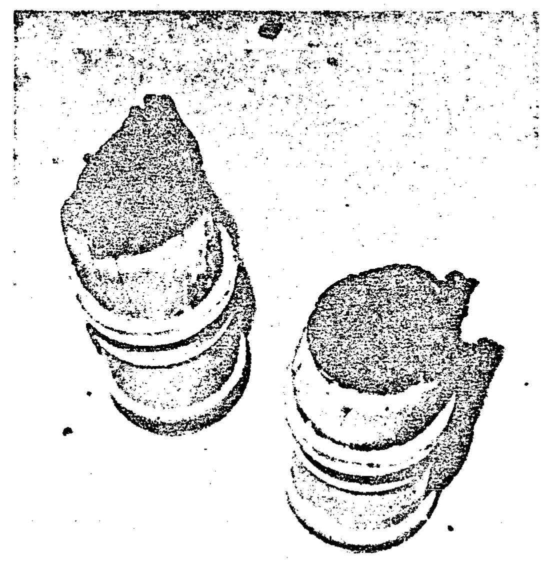

Figure 22 Horizontal branch pipes – test 2f showing rigid carbonised residue

residue will break down on prolonged exposure but will retard the penetration of fire through pipe and wall combinations.

Several tests demonstrate that the so called 'self-extinguishing' property of PVC is not maintained under conditions of elevated temperature. In this investigation PVC burned readily on several occasions when the lower compartment temperature exceeded 300°C. However, it was demonstrated that this burning could be contained within a floor-stopped shaft or similar arrangement. Figures 16, 17, 18 and 19 all show results where the stack in the lower compartments had burned vigorously but damage in the upper compartment was limited to distortion.

It must be noted here that on at least one occasion (during test 2f) the 100 mm PVC pipe burned with a flame within the furnace more readily than experience would have predicted. This led to the belief that there may be materials which, added to the PVC mix or otherwise used during manufacture, might change its combustion properties. Whether or not the use of these materials is permissible within the requirements of BS 4514:1969 is not clear.

Differences in the performances of the plastics materials examined, in this investigation other than PVC, were not such as to justify differentiating between them when defining their use. Their use should be restricted to the smaller sizes (see below). Test 2f suggests that the use of non-combustible metallic pipework – in this case cast-iron – may not necessarily lead to improved conditions. Although these pipes will maintain integrity through walls and fire stops more readily than plastics pipes, their greater thermal conductivity leads to the transfer of considerably more heat. In test 2f the upper compartment temperatures are seen to be considerably higher in the shaft using cast-iron (centre) than in the comparable one using PVC (left hand).

(g) Pipe size
Although tests 2a, b, c and d clearly demonstrate that the size of pipe passing into the protected shaft has a substantial effect within it, the variation due to pipe size is likely to diminish as the shaft or casing wall thickness increases; this effect is however small in comparison with heating in the enclosure due to conduction through the exposed wall. Although these four tests do not give a complete picture, a need to restrict the size of plastics pipes through protecting structures is demonstrated and since conditions adjacent to the shaft wall or casing cannot be controlled the restriction of pipe size to 100 mm diameter for PVC and 38 mm for other plastics appears to give a reasonable level of protection.

(h) Combinations of pipes
Although this effect was not investigated directly, comparison of the results of tests 2e and 2f suggests that if a 100 mm PVC pipe passes through the protecting element the addition of a limited number, (perhaps three,) of smaller pipes (38 mm or less) would not substantially worsen the condition. The proviso must be made that each additional smaller pipe must pass through the protecting element separately and be separately fire stopped. The passage of several pipes through a large hole which is subsequently fire stopped might well lead to the falling out of the stopping under fire conditions.

(i) Composite walls
Again, this effect was not examined. It is possible that a sandwich wall construction with a void in the centre would give a different performance from the homogeneous constructions examined. Comparable performance would probably be achieved if a non-combustible sleeving were used or if care were taken to ensure that solid, non-combustible fire stopping was continued into the void (see Figure 23).

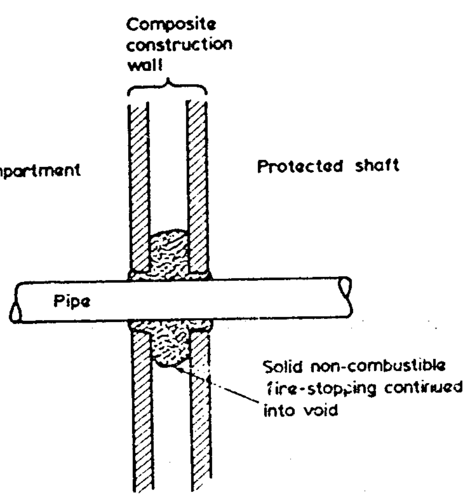

Figure 23 Suggested fire-stopping in walls of sandwich construction

(j) Sleeving
Sleeving of plastics pipes where they pass through walls has been proposed as a method of retarding integrity failure at the plane of division; nevertheless distortion and failure of the pipe is likely to occur at the ends of the sleeve and unless a rigid plug of decomposed plastic is formed within its length integrity of the whole system will be lost. It would seem that in small systems such as those primarily considered, the provision of sleeving is difficult due to lack of space and probably unnecessary. In larger installations sleeving might increase the effective thickness of an otherwise thin partition and is most useful if the pipes are not open. The sleeving should, however, not add to the fire hazard. The GRP wrapping examined gave off considerable amounts of dark smoke as well as combustible products. To make sleeving most effective a bond between the sleeve and the pipe is necessary, otherwise the softening pipe collapses away from the sleeve as shown in Figure 6 – test 1i. Metallic sleeving due to its high thermal conductivity would probably exaggerate this collapsing effect.

Where a plastics pipe is fitted onto a metal section to penetrate a division, failure of the junction is likely to occur on the unexposed face whenever pressure conditions are such that flow of hot gases from the fire area occurs.

(k) Support
Support for pipes on the exterior of the service duct is likely to be better in practice than in these experiments, and therefore likely to give improved fire performance. Inside protected shafts the complete collapse of the large diameter pipework due to softening is considered to increase unnessarily the problems associated with ignition and smoke production and metallic holding-brackets are recommended for use with 100 mm or 150 mm PVC pipes to offset this effect. This reaffirms a recommendation made in an earlier test report[3]. When metallic brackets were used no difference in performance was apparent between 'O' ring and solvent welded joints. Metallic brackets must of course be secured to a section of the shaft which will not itself fail under fire conditions.

(l) Pressures
The pressure of 1 mm wg maintained in most cases between the furnace and the outside was thought to provide a value consistent with the maximum likely pressure to which the pipe system would be exposed in practice. This pressure would usually be caused by superimposed wind effects and would in the majority of cases, be smaller resulting in a reduction of the effects shown by these tests.

(m) Larger installations
No conclusions are drawn regarding larger protected shafts than those likely to be used in domestic situations. Plastics pipes penetrating protecting structures will fail and this report can give some guidance as to the time at which failure will occur. Where shafts of larger size or

with greater fire loads are involved an assessment of the consequences of the initial failure into the protected shaft must be made in each individual case. As stated above, this investigation has not produced any evidence to suggest that the restrictions imposed by the amended Building Regulations are in general either too lenient or too prohibitive. However, this investigation suggests more stringent requirements than the regulations for the fire resistance of protecting casings.

2.8 Conclusions

This investigation was carried out with wall and shaft dimensions smaller than those encountered in practice. Notwithstanding this the following conclusions are believed to be justified.

1. Plastics pipework passing through walls will, in most instances, lead to loss of integrity of the wall under fire test conditions quicker than would be the case with most non-combustible pipework. Loss of integrity will be rapid if:

   (a) the pipework is open to the atmosphere (as in the case of drainage pipework)

   (b) the wall is thin

   (c) the pipe diameter is large.

   (Limited quantitative data is given in Table 4 and in Part 1.)

2. Plastics materials which do not melt and drip under fire conditions and which decompose to leave a carbonaceous residue are better for the maintenance of the integrity of a pipe/wall combination. PVC was the best of the materials investigated.

3. It is practicable to lay down design criteria if, for the domestic situation, failure is deemed to have occurred only when fire penetrates from one compartment to another.

4. The production of smoke and noxious gases should be the major cause for concern when considering the performance of plastics piping systems in fire. Rigid checks should be applied to ensure that no easy paths for the passage of smoke exist between compartments.

5. Flaming was not a problem in the tests and if occurring in practice would probably be satisfactorily contained within an installation comprising a structural wall and casing having a reduced fire resistance requirement.

6. Casings for enclosures should be require to have a minimum thickness and a specified degree of resistance to fire from either side.

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4 Ad hoc fire tests on PVC services in buildings. Joint Fire Research Organization Special Investigation 9116. Available from British Plastics Federation, 5 Belgrave Square, London W1.

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ACKNOWLEDGEMENTS

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Thanks are also due to the British Plastics Federation who provided the pipework.

Table 1 Pipe samples tested

Size (mm) nom.dia.	Material	Comments
50	Chlorinated polyvinyl chloride (CPVC)	All these materials are currently used for lateral pipe work in drainage installations. Further information is given in Appendix 3.1.
50	Polypropylene (PP)	
50	High density polyethylene (HDPE)	
50	Acrylonitrile butadiene styrene (ABS)	
100	Polyvinyl chloride (PVC)	This is currently virtually the only plastics material used in the UK for vertical drainage stacks. (ABS is used in the USA). The 100 mm size is commonly used; although larger sizes are available they were not examined.

Table 2 Wall constructions tested

Thickness (mm)	Material	Comments
9	Asbestos wall board (ASB)	In all cases pipes were made a tight fit into the wall or fire stopped with plaster.
50	Lightweight building blocks . . .(BB)	
100	Lightweight building blocks . . .(BB)	

Table 3 End conditions of pipes

Arrangement		Comments
90° bend and an open vertical section . . . open	Figure 3	The open or sealed arrangements represented the possible passage of fire towards an open stack or towards a water seal respectively. The T-junction arrangement gave better support on the unexposed side than the bend arrangement and is the more normal occurrence.
90° T-junction and an open vertical section . . . open	Figure 4	
90° T-junction and a closed vertical section . . . sealed		

Table 4 Tests to determine the integrity of simple pipe/wall combinations

Test	Pipe	Wall	Unexposed side	Differential pressure (Furnace/outside) mm wg	Sleeving	Test duration* min	Time to loss of integrity min	Comments
1a (Fig 3)	50 mm dia CPVC	9 mm asbestos board	Bend (Fig 3) Open	1	None	20	4 – 6 (all)	Rapid softening. Weight of pipe (not well supported) pulled it from partition (Fig 5)
1b	50 mm dia HDPE PP ABS	50 mm building blocks	Bend Open	1	None	12	5 HDPE, PP, ABS 9 CPVC	As above. Extra thickness of wall gives better support. Some carbonisation of CPVC noted.
1c	As for Tests 1a and 1b	100 mm building blocks	Bend Open	1	None	22	5 – 8 HDPE, PP, ABS To end CPVC	As above, extra thickness again being important.
1d	As for Tests 1a and 1b	100 mm building blocks	T-junction Open	1	None	55	11 HDPE 22 PP 25 CPVC 55 ABS	As above, also better support for weight of vertical pipes. ABS sealed itself on exposed face keeping temperature within pipe down†
1e	As for Tests 1a and 1b	9 mm asbestos board	T-junction Open	Zero	None	30	9 ABS 10 PP 17 HDPE 22 CPVC	All pipes other than CPVC flamed on exposed face at some time during test.
1f	As for Tests 1a and 1b	100 mm building blocks	T-junction Sealed	0.25–0.5	None	120	50 HDPE 82 PP Duration of test CPVC, ABS	Flaming after breakthrough. Compare with 1d
1g	As for Tests 1a and 1b	50 mm building blocks	T-junction Sealed	0.25–0.5	None	60	29 HDPE 34 PP Duration of tests CPVC, ABS	
1h	100 mm dia PVC	50 mm building blocks	Bend (x) 'O' ring joint (y) Cemented joint Open	1	None	12	10 (x) 10 (y)	No significant difference between (x) and (y). Weight of pipe pulled it from the partition.
1i	100 mm dia PVC	50 mm building blocks	T-junction Cemented joints Open	1	(a) None (b) 0.6 m length of GRP sleeve	21	13 (a) 15 (b)	Softening of pipe caused it to pull away from partition or protection. Figs 6 or 7.
1j	100 mm dia PVC	100 mm building blocks	T-junction (a) Cemented joint (b) 'O' ring joint Sealed	1	(a) None (b) 0.6 m length of GRP sleeve	25	23 (a) 20 (b)	As above
1k	100 mm dia PVC	50 mm building blocks	T-junction 'O' ring joints Sealed	Average of 0.04, varying from 0.02–1.0	(a) None (b) 0.6 m length of GRP sleeve	45	32 (a) duration of test (b)	
1l	100 mm dia PVC	100 mm building blocks	T-junction 'O' ring joints Sealed	Reduced	(a) None (b) 0.6 m length of GRP sleeve	70	63 (a) Duration of test (b)	Compare with 1j. Flaming and copious smoke and fumes after breakthrough.

*The heating conditions specified in BS 476:Part 8:1972 were used in all tests except 1e which was run at reduced temperatures.
†See page 3

Table 5 Results of tests on protected pipe systems

Test	Exposed wall	Pipes (open) through exposed wall	Pipes (sealed) through side and back walls of lower compartment	Maximum† temperatures in °C at 30, 60 and 90 min: Upper compartment	Stack	Lower compartment
2a (Fig 16)	50 mm building blocks and 12 mm asbestos wall board	Left: 50 mm CPVC	None	40 50 80	160 210 310	70 110 160
		Centre: 38 mm CPVC		40 60 70	120 140 190	90 120 150
		Right: 25 mm CPVC		40 50 60	50 80 120	60 60 80
2b (Fig 17)	38 mm asbestos wall board	Left: 50 mm ABS	None	40 80 100	100 230(P) 350	110 220 290
		Centre: 38 mm ABS		40 70 90	130(P) 200 200(P)	120 190 290
		Right: 25 mm ABS		30 60 70	100 140 170	120 160 190
2c	38 mm asbestos wall board	Left: 50 mm PP	None	40 70 90*	190 210(P) 290(P)*	160 250 270*
		Centre: 38 mm PP		40 70 80*	100 200(P) 200(P)*	150 220 230*
		Right: 25 mm PP		20 50 70*	80 130 150*	80 140 160*
2d (Fig 18)	12 mm asbestos wall board	Left: 50 mm PP	50 mm PP through 63 mm asbestos wall board side	90 140 –	220(P) 410 –	240 430 –
		Centre: 38 mm PP	–	80 110 –	230 400 –	200 360 –
		Right: 25 mm PP	25 mm PP through 63 mm asbestos wall board side	80 100 –	160 200 –	210 300 –

† Temperatures given are taken from experimental records and may differ slightly from those shown in the simplified curves
(P) Refers to peak temperatures reached prior to time specified
* Temperatures at 75 min

Test duration min	Comments
120	All branch pipes maintained a degree of integrity until 20 min when traces of smoke appeared in the lower compartments. Little smoke until 60 min. **Left:** Stack in lower compartment collapsed progressively from 80 min and began to burn at 117 min. **Centre:** Stack performed as above but later, collapsing from 100 min (Fig 16) **Right:** Stack was substantially intact at end. No loss of integrity to upper compartments.
100	Lower compartments filled with smoke earlier than for 2a (above). **Left:** Stack distorted at 45 min but steel bracket helped to retard collapse. At 95 min, following collapse, burning began. Stack in upper compartment appeared to soften. **Centre:** As above but changes were delayed. **Right:** Stack had distorted more than in 2a (above) but had not collapsed.
75	Results were similar to 2b (above). **Left:** Temperatures in stack and lower compartment initially rose more rapidly than in 2b, probably due to rapid melting of polypropylene. After 60 min, conditions were comparable with 2b (above). **Centre:** As for left **Right:** Earlier tempeature rise not exhibited as compared with 2b (above.)
65	Results similar to 2c above but with thin exposed wall and presence of other pipes through side walls the temperatures rose more quickly. There was no apparent loss of integrity to the upper compartments. **Left:** Stack distorted at 16 min and collapsed at 25 min in the lower compartment. Burning began at 45 min and led to softening and distortion in the upper compartment (Fig 18). Branch pipe through side wall failed at 61 min. **Centre:** Stack performed as above but burned later at 57 min. **Right:** As above but stack burned at 65 min. Branch pipe remained intact.

Continued overleaf

Table 5 Results of tests on protected pipe systems (continued)

Test	Exposed wall	Pipes (open) through exposed wall	Pipes (sealed) through side and back walls of lower compartment	Maximum† temperatures in °C at 30, 60 and 90 min		
				Upper compartment	Stack	Lower compartment
2c (Fig 19)	100 mm building blocks	**Left:** 100 mm PVC with 38 mm PP above it	100 mm PVC through 25 mm asbestos wall board side 38 mm PP through 6 mm asbestos board back	80 120 –	350(P) Burning –	250 370 –
		Centre: 100 mm PVC with 38 mm CPVC above it	100 mm PVC and 38 mm CPVC through 6 mm asbestos board back	80 120 –	320(P) Burning –	260 380 –
		Right: 100 mm PVC with 50 mm CPVC above it	100 mm PVC through 25 mm asbestos wall board side 50 mm CPVC through 6 mm asbestos board back	80 120 –	400(P) Burning –	210 290(P) –
2f (Figs 20–1)	12 mm asbestos wall board	**Left:** 100 mm PVC with 25 mm PP above it	100 mm PVC and 25 mm PP through 100 mm building block back	90 130 150	320(P) Burning Burning	250 420 590
		Centre: 100 mm cast iron	100 mm cast iron through 100 mm building block back	120 210 280	590 650(P) 700	250 450 570
		Right: 100 mm PVC with 50 mm ABS above it	100 mm PVC and 50 mm ABS through 100 mm building block back	280 540 630	240(P) Burning Burning	310 580 600

† Temperatures given are taken from experimental records and may differ slightly from those shown in the simplied curves
(P) Refers to peak temperatures reached prior to time specified
* Temperature at 75 min

Test duration min	Comments
60	Similar results were obtained from all three shafts, the lower compartment temperatures being very similar. All sealed pipes except that of 100 mm PVC in the centre compartment retained their integrity till the end of test. Considerable flaming occurred when test stopped. **Left:** Stack burned at 50 min, when recorded, lower compartment temperature was about 300°C. PVC and PP pipes through side and back retained integrity to end of test. **Centre:** Stack burned at 52 min. 38 mm CPVC pipe through back retained integrity to end of test but 100 mm PVC also through the 6 mm asbestos board failed at 44 min. **Right:** Stack burned at 50 min. PVC and CPVC pipes through side and back retained integrity to the end of test.
90	**Left:** Temperature conditions in the lower compartment were similar to 2e (above), with burning at 50 min. The 100 mm PVC and 25 mm PP pipes through the back wall softened and sagged at 88 min. Deformation of the stack in upper compartment but no loss of integrity. **Centre:** Cast iron pipe remained intact throughout. Temperature in the upper compartment rose faster than in all other tests and reached 280°C. **Right:** NO FLOOR STOP. All temperatures rose more rapidly than in left shaft. Integrity between upper compartment and outside was lost when the upper 100 mm PVC branch failed at 49 min. Pipes from the back of the lower compartment softened and sagged at about 86 min similar to left shaft.

Table 6 Minimum thickness of shaft or casing wall

Fire resistance requirement–h	Minimum wall thickness* mm
½	12
1	25
1½	25
2	38

*The thicknesses recommended relate only to the materials tested (asbestos wall board, blockwork etc). Non-combustible materials of lower density and combustible materials require special consideration.

APPENDIX I

Pipe dimensions

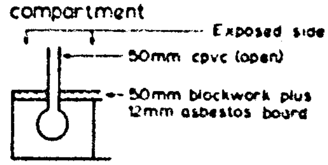
Material	Nominal diameter mm	OD mm	Wall thickness mm	CP 304 equivalent* wall thickness/OD mm
ABS CPVC and PP	25			
	38	42.9	1.9	1.5/40
	50	55.9	2.0	2.0/50
HDPE	25			
	38	44.5	3.0	
	50	57.2	3.0	

*Under ISO 161 plastics pipes sizes will require designation in terms of outside diameter. The values given in CP 304 are expressed similarly and are provided here for information.

APPENDIX II

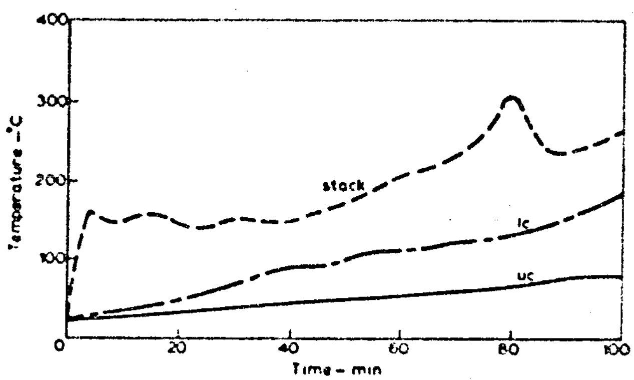
Test 2a Left hand compartment

Basic arrangement
For more detail
see figure 12



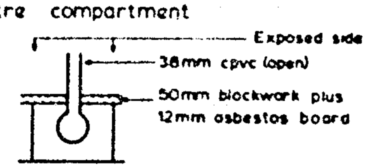
Comments

Stack collapsed at about 80 minutes
Test continued to 120 minutes
Burning in lower compartment at 117 minutes
After test results shown in figure 16



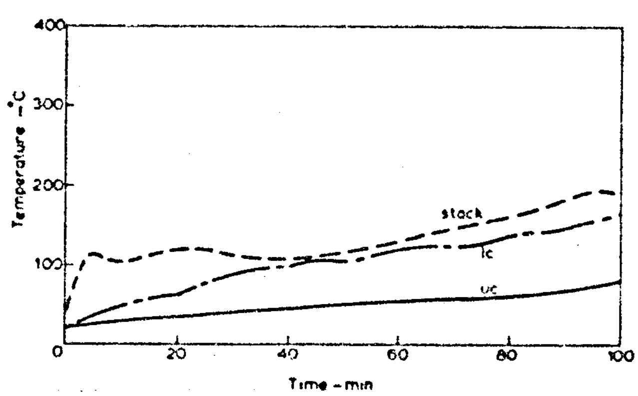
Test 2a Centre compartment

Basic arrangement
For more detail
see figure 12



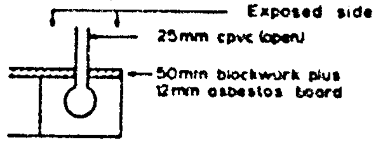
Comments

Test continued to 120 minutes
After test results shown in figure 16
No apparent burning



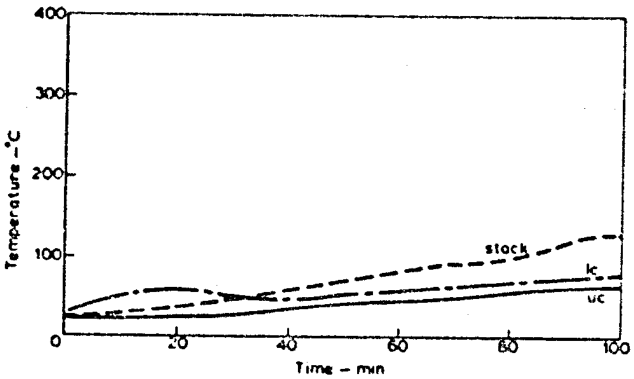
Test 2a Right hand compartment

Basic arrangement
For more detail
see figure 12



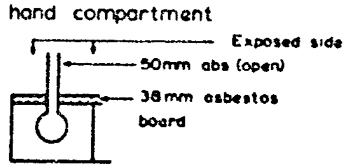
Comments

Test continued to 120 minutes
After test results shown in figure 16
No burning



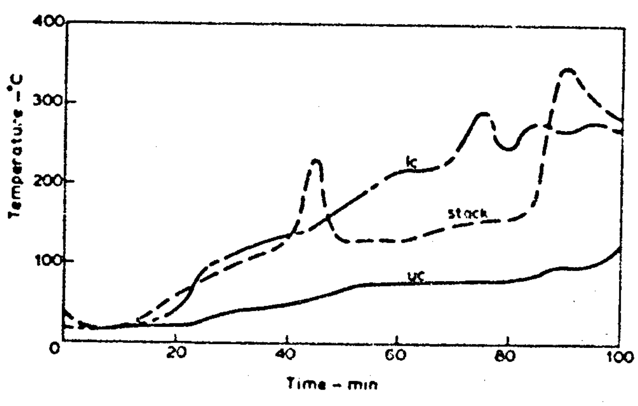
Test 2b Left hand compartment

Basic arrangement
For more detail
see figure 12



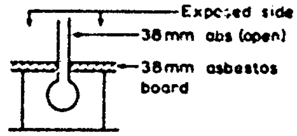
Comments

Excessive distortion of stack at 45 minutes
Burning apparent at 95 minutes — this record
suggests earlier ignition (85 minutes)



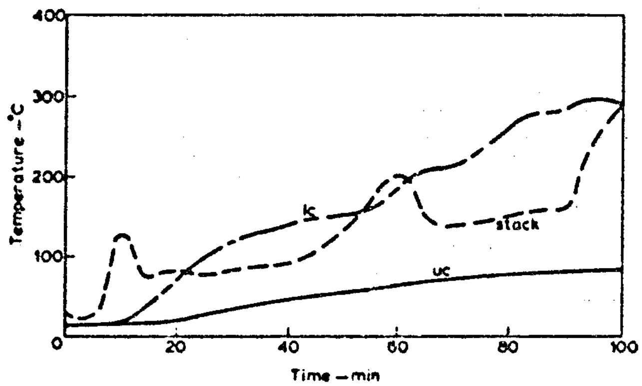
Test 2b Centre compartment

Basic arrangement
For more detail
see figure 12



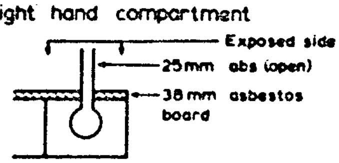
Comments

Excessive distortion of stack at 58 minutes
No apparent burning



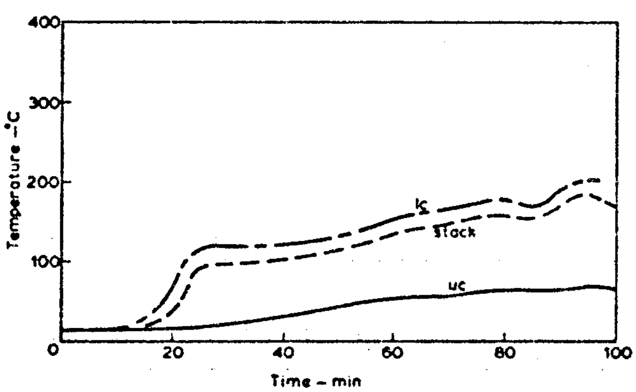
Test 2b Right hand compartment

Basic arrangement
For more detail
see figure 12



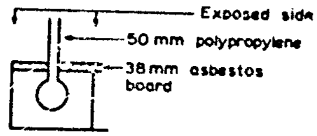
Comments

Excessive distortion of stack at 83 minutes
No burning



Test 2c

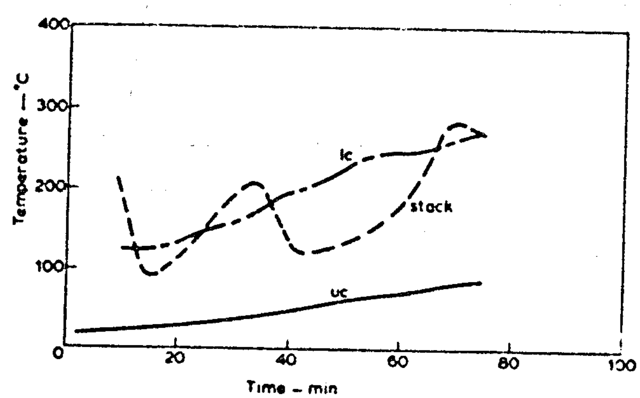
Left hand compartment



Basic arrangement
For more detail
see figure 12

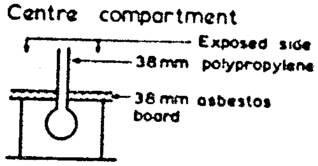
Comments

Excessive distortion of stack - 25 minutes
No burning



Test 2c

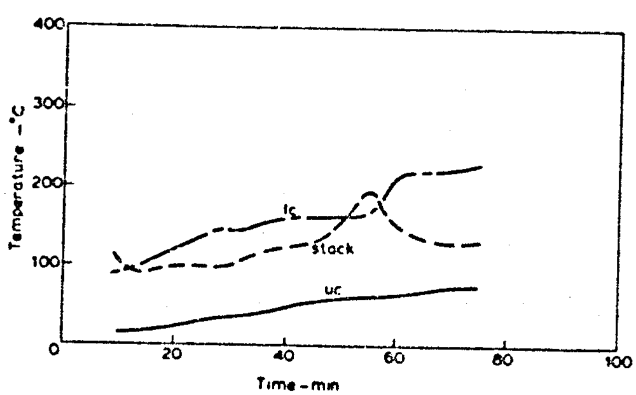
Centre compartment



Basic arrangement
For more detail
see figure 12

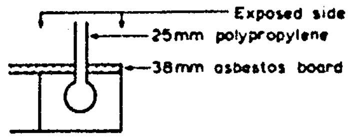
Comments

Distortion of stack 55 minutes
No burning



Test 2c

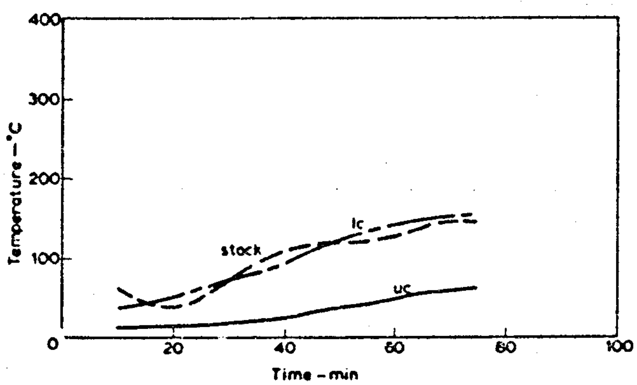
Right hand compartment



Basic arrangement
For more detail
see figure 12

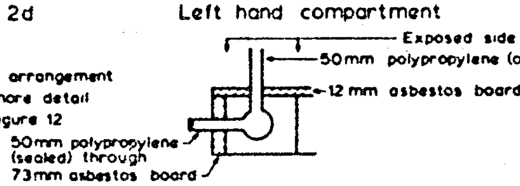
Comments

No burning



Test 2d

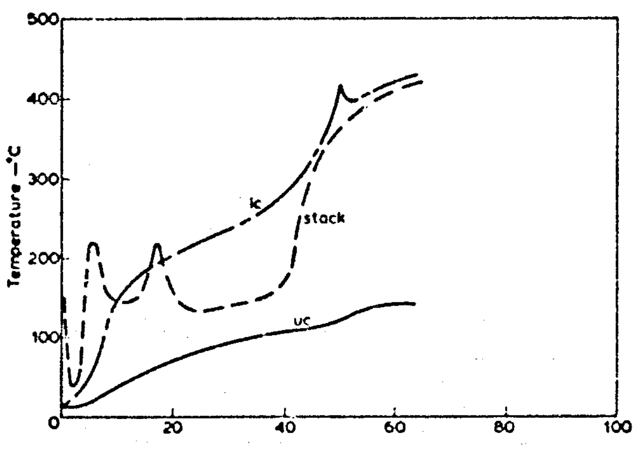
Left hand compartment



Basic arrangement
For more detail
see figure 12

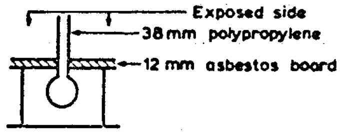
Comments

Burning apparent at about 45 minutes



Test 2d

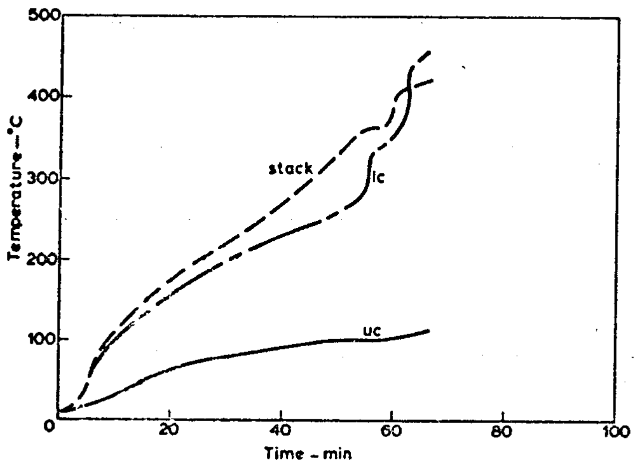
Centre compartment



Basic arrangement
For more detail
see figure 13

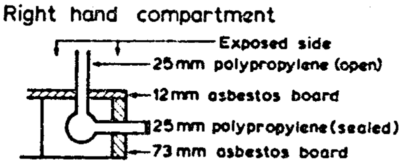
Comments

Burning apparent just before 60 minutes



Test 2d

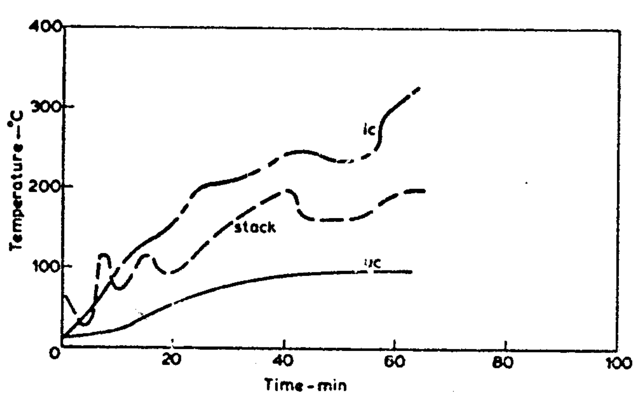
Right hand compartment



Basic arrangement
For more detail
see figure 13

Comments

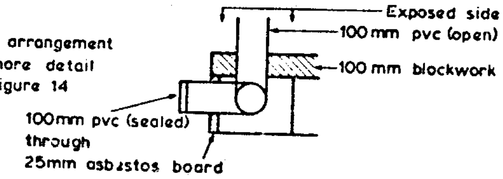
No burning



Test 2e

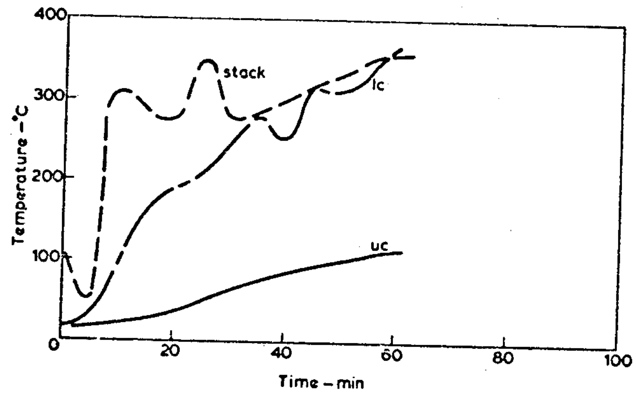
Left hand compartment

Basic arrangement
For more detail
see figure 14



Comments

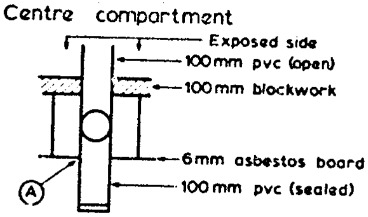
No apparent burning



Test 2e

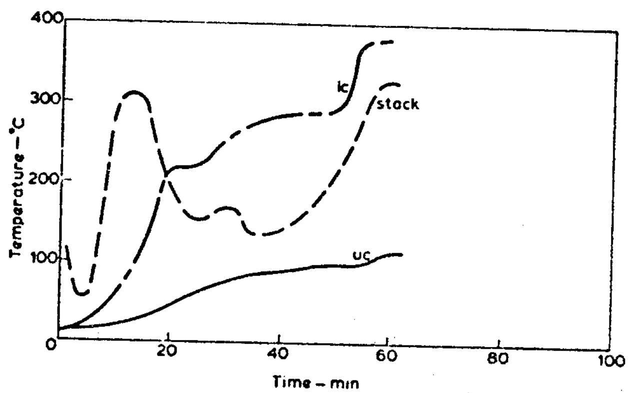
Centre compartment

Basic arrangement
For more detail
see figure 14



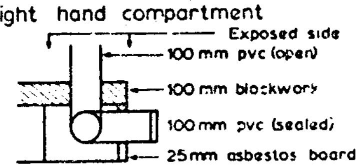
Comments

Failure at point A at 44 minutes
Burning at 52 minutes



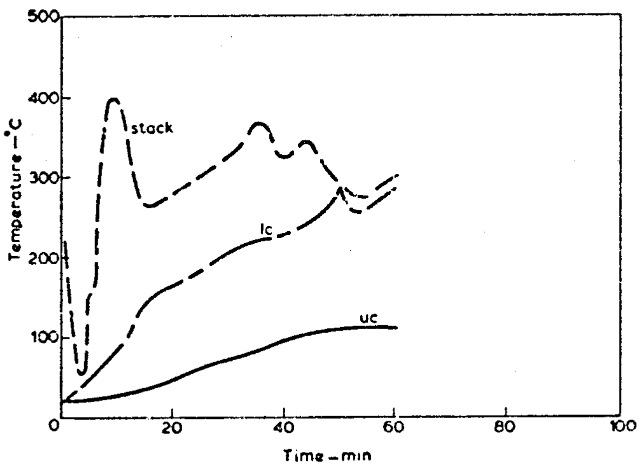
Test 2e

Right hand compartment



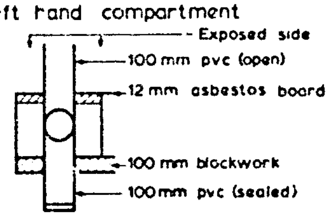
Basic arrangement
For more detail
see figure 14

Comments
Burning at 50 minutes



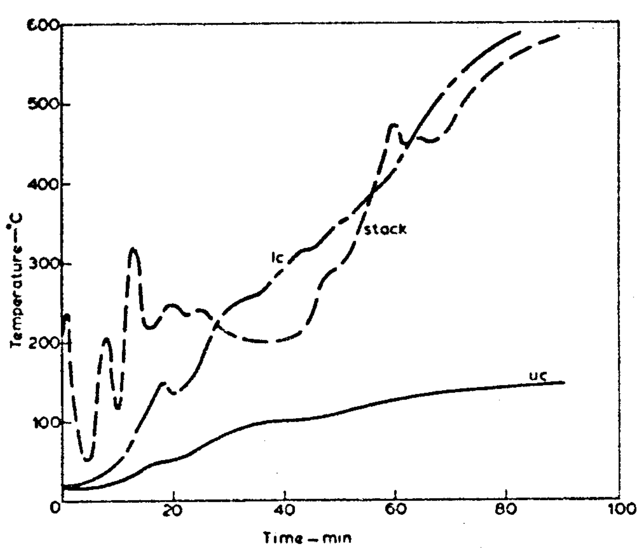
Test 2f

Left hand compartment



Basic arrangement
For more detail
see figure 15

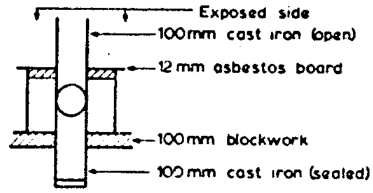
Comments
Burning just prior to 50 minutes



Test 2f

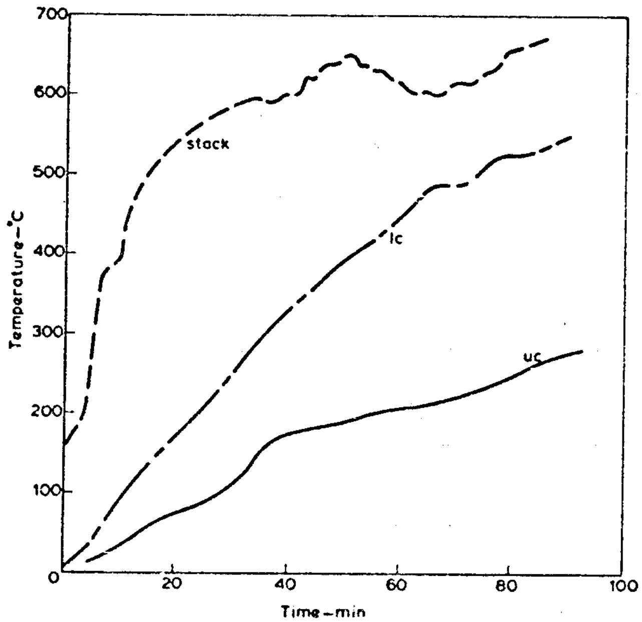
Centre compartment

Basic arrangement
For more detail
see figure 15



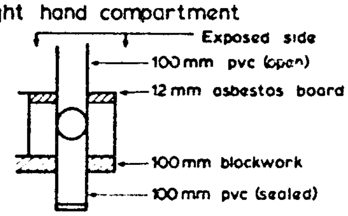
Comments

Compare uc temperatures with 2(d) – lefthand



Test 21 Right hand compartment

Basic arrangement
For more detail
see figure 15

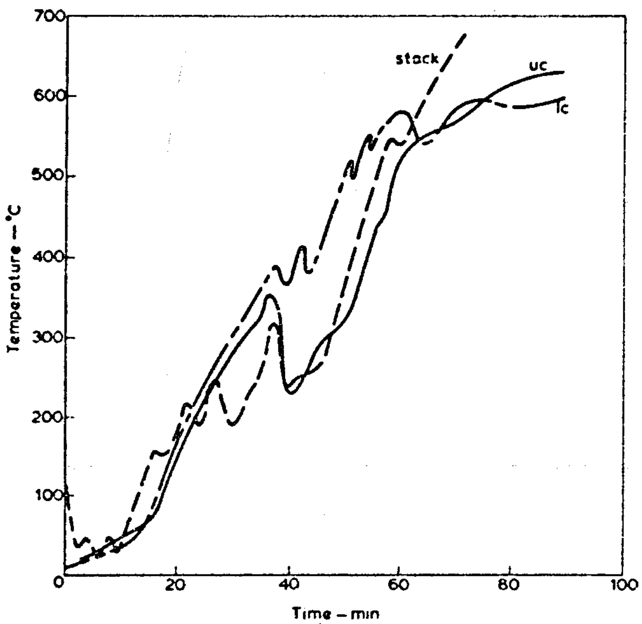


Comments

No floor stop

Note excessive upper compartment temperatures

Burning at 43 minutes



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CP63/76	Report on the burning of wood treated with wood preservatives containing copper, chromium and arsenic.	A J DOBBS and C GRANT
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CP65/76	In-situ and laboratory tests on glacial clays at Redcar.	A MARSLAND
CP66/76	Some trends in furniture fires in domestic premises.	S E CHANDLER
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CP2/77	Floor loadings in domestic buildings – the results of a survey.	G R MITCHELL and R W WOODGATE
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continued

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CP25/77	A simple pull-out test to assess the strength of in-situ concrete.	A J CHABOWSKI and D W BRYDEN-SMITH
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Fire spread and plastics pipes
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